COLONIAL NATIONAL HISTORICAL PARK

GEOLOGIC RESOURCE MANAGEMENT ISSUES

SCOPING SUMMARY

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Shoreline preservation structures at Colonial National Historical Park. Photograph by Melanie Ransmeier, Geologic Resources Division, National Park Service.

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Executive Summary

A Geologic Resource Evaluation scoping meeting and field trip for Colonial National Historical Park took place at Yorktown, VA on August 1, 2005. The scoping meeting participants identified the following list of geologic resource management issues. These topics are discussed in detail on pages 14- 21.

1. Coastal and marine issues including sediment transport and erosion, storm damage and flooding, shoreline stabilization practices, and shoreline evolution

2. Connections between geology, and other disciplines including archaeology and history, pertaining to pre- settlement Native American sites, colonial areas, and battlefields

3. Paleontological resource potential especially along ravines cut into the Yorktown Formation

4. Karst features including sinkholes and ponds

5. Stratigraphic characteristics including shrink and swell clays, seeps and springs along impermeable layers, cliff formation, etc.

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Introduction

This report briefly describes the general geology of Colonial National Historical Park (COLO), including a geologic history of the park, geologic resource management issues in the park, and the status of Geologic Resource Evaluation (GRE) digital geologic mapping projects related to the park. The National Park Service held a Geologic Resource Evaluation scoping meeting for Colonial National Historical Park in Yorktown, Virginia on Monday, August 1, 2005. The purpose of the meeting was to discuss the status of geologic mapping in the park, the associated bibliography, and the geologic issues in the park. Products derived from the scoping meeting are: (1) digitized geologic maps covering the park; (2) an updated and validated bibliography; (3) a scoping summary (this report); and (4) a Geologic Resource Evaluation Report which brings together all of these products.

Colonial National Historical Park was established during Herbert Hoover's administration as a national monument on June 3, 1930. National Historic Park status was gained under Franklin D. Roosevelt's administration on June 5, 1936. The park preserves wild space between Jamestown and Yorktown, Virginia connected by the 37 km (23 miles) long and 165 m (~500 ft) wide Colonial Parkway. It commemorates early colonial efforts as well as the decisive battlefield of the Revolutionary War and remnants of Civil War use. Colonial National Historical Park covers 8,677 acres of eastern Atlantic Coastal Plain near Williamsburg, VA.

Map Notes

The Inventory and Monitoring Program and Colonial National Historical Park identified 7 quadrangles of interest (Figure 1). These 7 quadrangles sit within the Williamsburg 30'x60' quadrangle, however, no known geologic maps are published for this quadrangle. The Virginia Division of Mineral Resources has published the following 1:24,000 scale 7.5' quadrangle maps covering all but the Clay Bank and Surry quadrangles:

Bick, K.F. and Coch, N.K., 1969, Geology of the Williamsburg, Hog Island, and Bacons Castle quadrangles, Virginia: Geologic Map of the Williamsburg Quadrangle, Virginia (plate 1 / 3), Virginia Division of Mineral Resources, Report of Investigations 18, plate 1 / 3, 1:24,000 scale (GMAP_ID 2462).

Bick, K.F. and Coch, N.K., 1969, Geology of the Williamsburg, Hog Island, and Bacons Castle quadrangles, Virginia - Geologic Map of the Hog Island Quadrangle, Virginia (plate 2 / 3), Virginia Division of Mineral Resources, Report of Investigations 18, 1:24,000 scale (GMAP_ID 5424).

Johnson, G.H. and Berquist, C.R., Jr., 1988, Geology and Mineral Resources of the Brandon and Norge quadrangles, Virginia, Virginia Division of Mineral Resources, Publication 87, 1:24,000 scale (GMAP_ID 2464).

Johnson, G.H, 1972, Geology of the Yorktown, Poquoson West, and Poquoson East quadrangles, Virginia - Plate 1: Geologic Map of the Yorktown Quadrangle, Virginia, Virginia Division of Mineral Resources, Report of Investigations 30, 1:24,000 scale (GMAP_ID 2463).

Johnson, G.H., 1972, Geology of the Yorktown, Poquoson West, and Poquoson East quadrangles, Virginia - Plate 2: Geologic Map of the Poquoson West Quadrangle, Virginia, Virginia Division of Mineral Resources, Report of Investigations 30, 1:24,000 scale (GMAP_ID 5426).

The Virginia Division of Mineral Resources has a geologic mapping project for the Williamsburg 30'x60' sheet in progress and updated geologic mapping exists for parts of the Surry quadrangle and several others of interest. Rick Berquist of the College of William and Mary is in the process of completing these projects.

Many other maps exist for the region including coverage of the geology, structural geology, surficial geology, topography, aeromagnetic- gravity, mineral and mineral potential, etc. These maps are available from agencies such as the U.S. Geological Survey, the Virginia Division of Mineral Resources, and the Maryland Geological Survey.

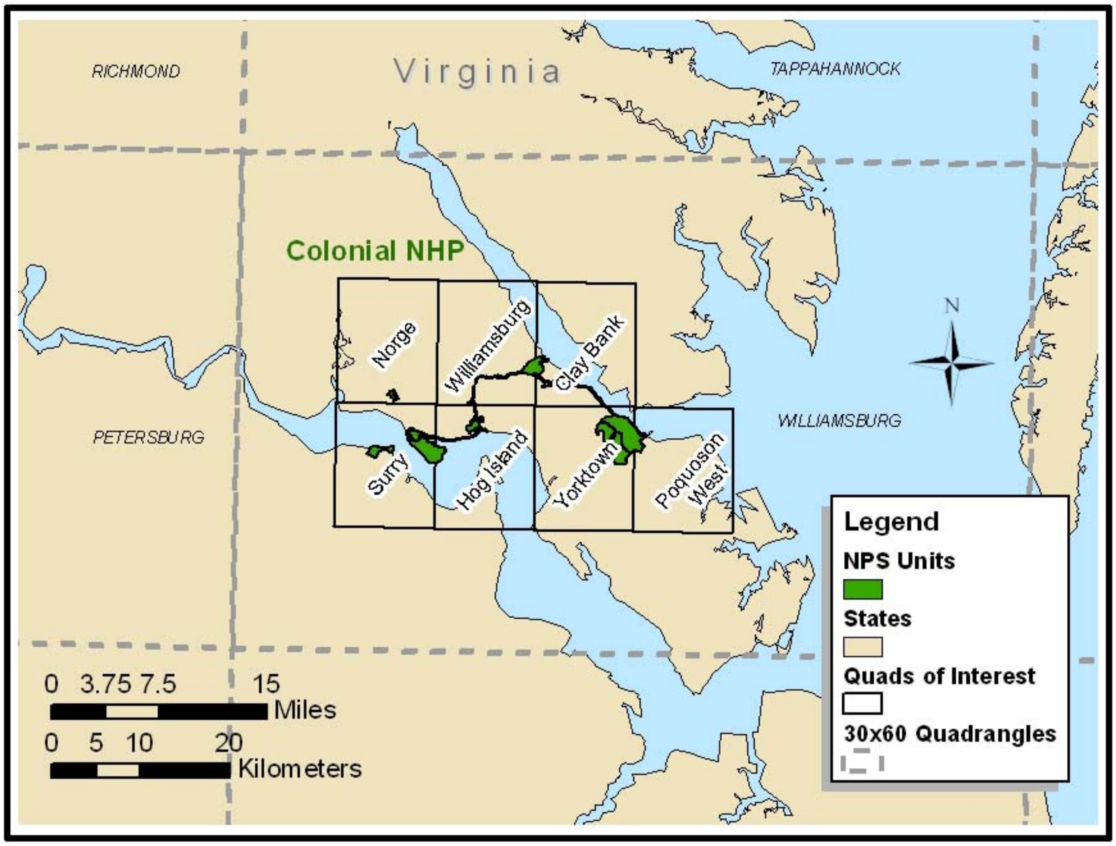

Figure 1. COLONIAL NATIONAL HISTORICAL PARK Quadrangles of Interest

Mapping Deliverables

Colonial National Historical Park has unpublished digital geologic data for much of the park and limited surrounding areas. This unpublished geologic data is part of the current Williamsburg 30'x60' mapping effort by the Virginia Division of Mineral Resources. The GRE team will obtain these data from the park and work with the Virginia Division of Mineral Resources and Rick Berquist to update this data, fill in gaps, and incorporate it into the GRE programs GIS data model.

A conference call including representatives from the Virginia Division of Mineral Resources and the GRE team is scheduled for Fall of 2005 to address mapping priorities and opportunities for collaboration with the NPS. During the conference call mapping projects pertinent to COLO, including mapping of the Clay Bank and Surry Quadrangles will be discussed.

Physiography

Colonial National Historical Park lies within the Atlantic Coastal Plain physiographic province near the interface between the upland and lowland subprovinces. Elevations in these subprovinces range from 20 to 80 m (60- 250 ft) and 0 to 20 m (0- 60 ft), respectively. Colonial National Historical Park straddles the peninsula between the James and York Rivers just north of the Tidewater area of Virginia. The landscape ranges from the tidally influenced marshy lowlands of Jamestown Island, to eroded rolling hills of the peninsula to the deeply scoured heights above the York River at Yorktown.

In the area of Colonial National Historical Park, the eastern United States is divided into 5 physiographic provinces with associated local subprovinces. These are, from east to west, the Atlantic Coastal Plain, the Piedmont Plateau, the Blue Ridge, the Valley and Ridge, and the Appalachian Plateaus provinces (Figure 2).

The “Fall Line” or “Fall Zone” marks a transitional zone where the softer, less consolidated sedimentary rock of the Atlantic Coastal Plain to the east intersects the harder, more resilient metamorphic rock of the Piedmont to the west to form an area of ridges, waterfalls, and rapids.

The Atlantic Coastal Plain province is primarily flat terrain with elevations ranging from sea level to a maximum of about 100 m (300 ft) in Maryland. Sediments eroding from the Appalachian Highland areas to the west formed the wedge- shaped sequence of soft sediments that were deposited intermittently on the Atlantic Coastal Plain during periods of higher sea level over the past 100 million years. These sediments are now more than 2,438 m (8,000 ft) thick at the Atlantic coast and are reworked by fluctuating sea levels and the continual erosive action of waves along the coastline. Large streams and rivers in the Coastal Plain province, including the James, York, Rappahannock, and Potomac, continue to transport sediment and to extend the coastal plain eastward. Beyond the province to the east the submerged Continental Shelf province extends another 121 km (75 miles).

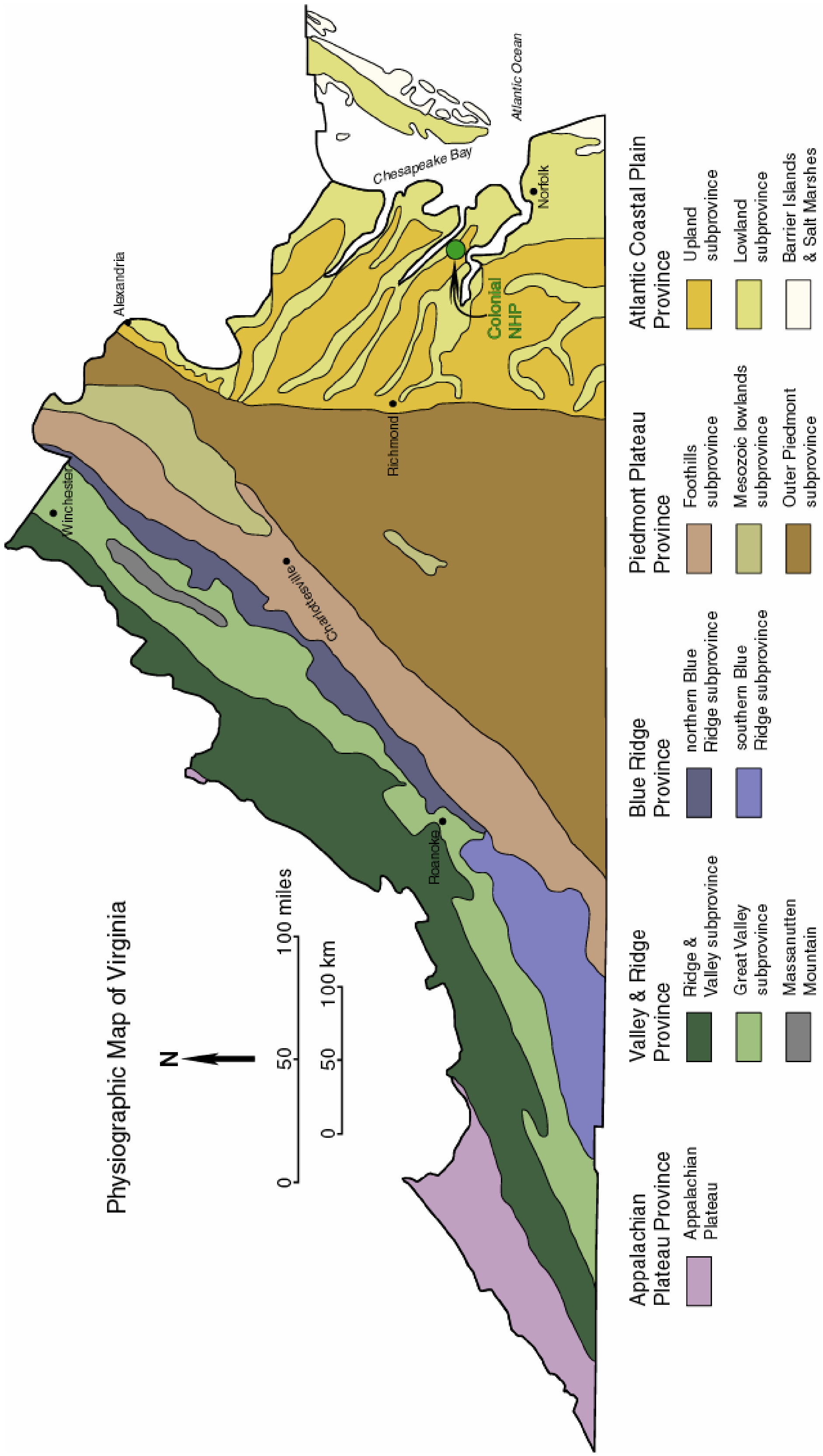

Figure 2: Location of Colonial National Historical Park relative to the physiographic provinces of Virginia. Graphic is adapted from Bailey (1999).

Geologic History of Southern Virginia

Proterozoic Era – In the mid Proterozoic, during the Grenville orogeny, a supercontinent formed which included most of the continental crust in existence at that time. The sedimentation, deformation, plutonism (the intrusion of igneous rocks), and volcanism associated with this event are manifested in the metamorphic gneisses in the core of the modern Blue Ridge Mountains (Harris et al., 1997). These rocks were deposited over a period of 100 million years and are more than a billion years old, making them among the oldest rocks known from this region. They form a basement upon which all other rocks of the Appalachians were deposited (Southworth et al., 2001).

The late Proterozoic, roughly 600 million years ago, brought a tensional, rifting tectonic setting to the area. The supercontinent broke up and a sea basin formed that eventually became the Iapetus Ocean. In this tensional environment, flood basalts and other igneous rocks such as diabase and rhyolite added to the North American continent. These igneous rocks were intruded through cracks in the granitic gneisses of the Blue Ridge core and extruded onto the land surface during the break- up of the continental land mass (Southworth et al., 2001). The Iapetus basin collected many of the sediments that would eventually form the Appalachian Mountains and Piedmont Plateau.

Early Paleozoic Era – From Early Cambrian through Early Ordovician time there was another period of orogenic activity along the eastern margin of the continent. The Taconic orogeny (~440- 420 Ma in the central Appalachians) was a volcanic arc – continent convergence. Oceanic crust, basin sediments, and the volcanic arc from the Iapetus basin were thrust onto the eastern edge of the North American continent. The Taconic orogeny involved the closing of the ocean, subduction of oceanic crust, the creation of volcanic arcs and the uplift of continental crust (Means, 1995). In response to the overriding plate thrusting westward onto the continental margin of North America, the crust bowed downwards to the west creating a deep basin that filled with mud and sand eroded from the highlands to the east (Harris et al., 1997). This so- called Appalachian basin was centered on what is now West Virginia.

This shallow marine to fluvial sedimentation continued for a period of about 200 million years during the Ordovician, Silurian, Devonian, Mississippian, Pennsylvanian, and Permian Periods, resulting in thick piles of sediments. The source of these sediments was from the highlands that were rising to the east during the Taconian orogeny (Ordovician), and the Acadian orogeny (Devonian). The Acadian orogeny (~360 Ma) continued the mountain building of the Taconic orogeny as the African continent approached North America (Harris et al., 1997). Similar to the preceding Taconic orogeny, the Acadian event involved land mass collision, mountain building, and regional metamorphism (Means 1995). This event was focused further north than southern Virginia.

Late Paleozoic Era – Following the Acadian orogenic event, the proto- Atlantic Iapetus Ocean completely closed during the Late Paleozoic as the North American continent collided with the African continent. This formed the Appalachian mountain belt we see today and the Pangean supercontinent. This mountain building episode, called the Alleghanian orogeny (~325 – 265 Ma), and was the last major orogeny of the Appalachian evolution (Means, 1995). During this orogeny, rocks of the Great Valley, Blue Ridge, and Piedmont provinces were transported as a massive block westward onto younger rocks of the Valley and Ridge. The amount of compression was extreme. Estimates are of 20- 50 percent shortening which translates into 125–350 km (75- 125 miles) of lateral translation (Harris et al., 1997).

Mesozoic Era – Following the Alleghenian orogeny, during the late Triassic, a period of rifting began as the joined continents began to break apart from about 230- 200 Ma. The supercontinent Pangaea divided into roughly the continents that exist today. This episode of rifting or crustal fracturing initiated the formation of the current Atlantic Ocean and caused many block- fault basins to develop with accompanying volcanism (Harris et al., 1997; Southworth et al., 2001). Thick deposits of unconsolidated gravel, sand, and silt were shed from the eroding mountains. These were deposited at the base of the mountains as alluvial fans and spread eastward to be part of the Atlantic Coastal Plain (Duffy and Whittecar 1991; Whittecar and Duffy, 2000; Southworth et al., 2001).

The amount of material that has been eroded from the Appalachian Mountains, as inferred from the now- exposed metamorphic rocks, is immense. Many of the rocks exposed at the surface must have been at least 20 km (~10 miles) below the surface prior to regional uplift and erosion. The erosion continues today with the Potomac, Rappahannock, Rapidan, James, and Shenandoah Rivers stripping the Coastal Plain sediments, lowering the mountains, and depositing alluvial terraces along the rivers, creating the present landscape.

Cenozoic Era – Since the breakup of Pangaea and the uplift of the Appalachian Mountains, the North American plate has continued to drift toward the west. The isostatic adjustments that uplifted the continent after the Alleghenian orogeny continued at a subdued rate throughout the Cenozoic Period (Harris et al., 1997). These adjustments may be responsible for occasional seismic events felt throughout the region.

The landscape at Colonial National Historical Park is profoundly impacted by the deposition of Tertiary and younger sediments and the subsequent erosion of these units by evolving waterways. The James and York Rivers and their associated wetlands, estuaries, and tributaries are among the major waterways in the Chesapeake Bay watershed. This natural riverine environment continues to cut terraces, entrench channels, shift bars and other sediments, and cut scarps and ravines as it responds to changes in climate, seasonal storms, and human influences.

Though glaciers from the Pleistocene Ice Ages never reached the southern Virginia area (the southern terminus was in northeastern Pennsylvania), the intermittent colder climates of the ice ages played a role in the formation of the landscape at Colonial National Historical Park. Freeze and thaw cycles within unconsolidated terrace units homogenized bedding features. Cold climate subaerial deposits contain fossils such as wooly mammoth, mastodon teeth, etc. Sea level fluctuations during ice ages throughout the Pleistocene caused the baselevel of many of the area's rivers to change. During lowstands (sea level drops), the rivers would erode their channels exposing the deformed bedrock of the Piedmont Plateau to the west. During oceanic highstands, the river basins flooded and deposition resulted in deposits of beach sediments in the park area.

Stratigraphy

Within the park and surrounding areas are younger deposits of Atlantic Coastal Plain rocks. At depth, the Cretaceous Potomac Formation underlies most of the coastal plain. Atop this unit lie the Aquia Formation, the Marlboro Clay, the Nanjemoy, Piney Point, Chickahominy, Old Church, St. Marys, Eastover, and Calvert formations (Johnson et al., 2001). These units are only locally accessible in drill cores.

The deepest ravines in the area cut into the Yorktown Formation that was deposited on top of the Calvert Formation. The Yorktown Formation is a maximum of 25 m (82 ft) thick, contains quartz and feldspar sands mixed with lesser clays, and silts as well as crossbedded shelly layers. This unit is overlain by the clay- rich Windsor and Sedley formations. The fine to coarse sand, gravel, silt and clay of the Windsor Formation is of lower Pleistocene to upper Pliocene age. This unit locally contains fossil burrows (Kenworthy and Santucci, 2003).

The Shirley Formation contains coarse sands, gravels, pebbles and occasional boulders from river terraces that are of the middle Pleistocene. This formation is rich in organic material including tree stumps and leaves and seeds of oak, cypress, and hickory trees (Kenworthy and Santucci, 2003). The upper Pleistocene Tabb Formation contains sands, gravels, silts and clays and underlies low terraces in the area. The Tabb Formation has three members: the Poquoson, the Lynnhaven, and the Sedgefield Members. The upper Pliocene Bacons Castle Formation includes gravelly sand and sandy- silty- clayey upper layers. These are often found in high- level terrace areas. The more recent deposits at the park include various Quaternary age units.

The youngest deposits at Colonial National Historical Park include thick alluvium deposits of sand, gravel, silt and clays as much as 15 m (49 ft) thick, beach and estuarine deposits, marsh and swamp deposits along waterways, shelly sands, and artificial fill from construction of roads, dams, bridges, landfills, and highways.

Significant Geologic Resource Management Issues

1. Coastal and marine issues

Many of the cultural features present at Colonial National Historical Park are located within several meters of the James and York Rivers. The dynamic geomorphic processes associated with these waterways constantly threaten nearshore and onshore resources. In the park area, the James and York rivers are affected by tidal fluctuations that are on average 2.5 m (7.5 ft). As such, local sea level rise of 2.1 mm/year (0.1 inches/year) has significant implications for resource management at Colonial National Historical Park (Johnson et al., 2001). There is a great need at the park to understand the nature of sediment transport along the shorelines.

Storm events such as nor'easters and hurricanes have dramatic effects on the landscape at the park. In 1985 a nor'easter tore up the pier and docks of Yorktown's waterfront area. Following this storm, 10,000 yards of beach fill and one breakwater were added to the landscape. In 2003, Hurricane Isabel produced 2 m (6 ft) tall waves per 5 seconds in the York River. The 12- hour surge associated with this event started from the north and swung towards the south as the storm passed. This effect concentrated erosive waves in several different directions against the shorelines of the park. In Yorktown, along the commercial waterfront some nearshore breakwaters and other shoreline stabilization structures were damaged and the beach was washed away. At Jamestown, several archaeological sites were washed away in the vicinity of Blackpoint.

Ongoing efforts to stabilize the shores at Colonial include instillation of breakwaters, riprap along reaches of the parkway, lines of rock, sand, marsh plants (creating a wetland area), stonewalls, beach replenishment, and vegetative interfaces. These measures have been met with mixed success. At Passmore Creek, the waterway bypassed a riprap structure and punctured a new channel, threatening cultural sites there. Rockwalls as high as 2 m (6 ft) were breached during Hurricane Isabel in 2003, carving a scarp only 1- 2 m (3- 6 ft) from the parkway in some places. The many breakwaters (installed in 1994, 2000, 2004-2005, etc.) along the York River have been successful in preserving a scalloped shoreline, only major storms are capable of compromising these structures.

The York River continues to transgress southwards through time. The southern shore of the river near Yorktown is eroding 2- 3 times faster than the northern shore at Gloucester Point.

Research and monitoring questions and suggestions include:

- Is current southward movement of the York River related to a radial fault from the Chesapeake Bay Impact structure?
- Research possible reasons the Gloucester area of the York River is relatively narrow.
- Perform several shoreline surveys per year to detect seasonal variations. Supplement these surveys with lidar, GIS surveys, and aerial photographs.
- Study erosion rates and processes in surrounding areas and relate to the sediment budget of the different watersheds.
- Monitor loss of ridges within wetland areas near Jamestown.
- Monitor topographic changes due to surface and cliff erosion.
- Promote coastal shoreline stability measures.
- Define the mappable shoreline in relation to tidal fluctuations.
- What are the effects of increased erosion on aquatic ecosystems at the monument?
- Should storm effects be remediated by the park in lieu of natural processes?
- Update the aerial mosaics for shoreline evolution since 1937.

2. Connections between geology and other disciplines

Archaeological sites and excavations are a major resource at Colonial National Historical Park. People were attracted to the area for settlement because of the unique geologic setting, which was rich in coastal resources and possessed a natural landing area, fresh water, timber, and waterways for navigation and trade. Changing water levels and brackish water encroachment may be among the reasons settlements were abandoned at Jamestown. Native American, as well as 17th and 18th century archaeological sites, are disappearing from the landscape due to shoreline erosion, wetland encroachment, storm events, and local development. Jamestown records almost 400 years of shoreline loss since the first landing in 1607. At that time, the shoreline probably lay more than 120 m (400 ft) to the west (Johnson et al., 2001). The isthmus that connected Jamestown Island to the mainland was breached in the late 18th century.

Blackpoint contained an early Native American site with a hearth. This area had to be excavated as a phase 3 excavation (salvage archaeology) to get whatever artifacts possible before the entire site was removed by erosion. In 2003 Hurricane Isabel removed meters of shoreline alone the James and York rivers. Treefall associated with the storm's high winds has exposed graves from the pre-settlement era through the Civil War. Erosion of the areas ridgelines has put approximately 60 significant sites at risk. A Confederate fort near Jamestown is eroding into the river. Areas especially susceptible to future flooding include Black Point, the Pitch and Tar trough, and the Passmore Creek lowlands (Johnson et al., 2001).

Geology also influenced the battles fought at Yorktown and the strategic movement of troops around the peninsula. The area's waterways facilitated and hindered the movement of troops in both the Revolutionary and Civil wars. British general Cornwallis was trapped against the bluffs at Yorktown, unable to cross the river to Gloucester due to inclement conditions. Confederates chose not to defend the town based on their knowledge of the landscape and its historical reputation. At Colonial, the morphology of the landscape follows the underlying stratigraphic structures.

Geologic processes also affect how these cultural features are preserved. Often geologic forces must be managed to prevent loss of cultural resources. The park is charged with maintaining the historic context of the landscape. This often means resisting natural geologic changes. Many of the historical features at the park have been lost to coastline erosion. The waterways are changing position constantly as part of natural meandering river flow. These shoreline changes threaten existing park facilities and the historical context of the landscape. Historic earthworks and structures are also threatened by erosion and weathering.

Research and monitoring questions and suggestions include:

- Create interpretive programs concerning geologic features and processes and their effects on the settlement history of the Colonial area.
- Encourage the interaction between geologists and the interpretive staff to come up with a list of features and programs to execute.
- Create a general interest map with simple explanatory text on geologic influences for visitors to the area.
- How did the areas geomorphology and landscape affect the battles fought at Colonial?

3. Paleontological potential

Though no formal paleontological inventory has been completed for Colonial, some of the first fossils described from North America were found in the Yorktown Formation. The Yorktown Formation is famously rich in fossil remains and fossils from this unit grace a number of museums around the world. This unit contains the Virginia State *Fossil (Chesapecten jeffersonius)*. Other fossils include 3 Ma sharks teeth, whale and walrus bones, gastropods, mollusks, osctracodes, foraminidera, bryozoans, brachiopods, echinoids, coral, sponge spicules, fish bones, and scallop shells (Kenworthy and Santucci, 1993). Incisement of the rivers and streams in the park area has created deep ravines into fossil- bearing beds of the Yorktown Formation. Remains of a wooly mammoth were exhumed by stream downcutting. These 20,000- year- old remains and other paleontological treasures need to be carefully catalogued and preserved.

Research and monitoring questions and suggestions include:

- Determine fossils resources obscured by riprap within Colonial National Historical Park.
- Conduct a formal paleontological inventory for the park.
- Use microfossils found near Jamestown to aid in the determination of paleoclimatic conditions and paleovegetation patterns.

4. Karst activity

Karstic landforms result from the unique juxtaposition of the clay rich Windsor Formation (~ 20- 25 m, 60- 85 ft above sea level) atop the relatively fossil shell rich carbonate Yorktown Formation (15 m, 50 ft above sea level). Acidic groundwater causes the dissolution of the carbonate layers. The overlying layers sink into the cavities left after dissolution. Karst landforms locally include sinkholes, wetlands, and seasonal ponds such as the Grafton Pond complex and Brackens Pond. Sinkhole formation threatens homes and buildings throughout the area. A karstic wetland developed in the yard of a home in the Queenslake subdivision near Williamsburg.

Cornwallis' Cave, a feature along the bluffs in Yorktown is man- made and not related to karst formation in the area. This feature is a cultural resource that contains holes carved in the stone cave walls for wooden beams (inhabited at some point?) and merits preservation.

Research and monitoring questions and suggestions include:

- Are current karst processes endangering areas within Colonial National Historic Site?
- Identify and monitor known karst areas to determine rates of change.

5. Stratigraphic characteristics

Atop the cliff- forming Yorktown Formation is a linear bed referred to as the Sedley Formation. This bed is typically 2- 3 m (7- 10 ft) thick and as much as 8 m (25 ft) thick in Suffolk, Virginia. This bed contains clayey silt and has high shrink- and- swell potential. This unit caused significant problems in recent road and building developments near Williamsburg including the Queenslake subdivision.

The Bacons Castle Formation has a high gravel content. These coarse- grained beds are highly permeable. This unit sits atop the clay rich Windsor Formation which acts as an aquitard, blocking vertical groundwater flow. The groundwater flows laterally along the top of the Windsor to a cliff face or ravine and emerges as a spring or seep. These features are prominent in higher elevations of the peninsula.

Research and monitoring questions and suggestions include:

- Does the Sedley Formation represent prodelta clays during marine transgression atop the Yorktown Formation?
- Is spring flow concentrated along the top of the Yorktown Formation?
- Inventory and monitor all springs and seeps for flow and water quality.
- Identify potential shrink- and- swell clay problem areas to avoid for future development of administrative and visitor facilities.

6. Seismicity

The Chesapeake Bay impact structure to the southeast of the park is still downloading and causes frequent small magnitude (~2) earthquakes. These earthquakes are occurring during the shift of blocks along concentric, listric faults. Much of Colonial National Historic Park is located on a subsiding side of a rotating fault- bounded block (Johnson et al., 2001). Earthquakes may cause significant damage to buildings, fences and other cultural features at Colonial National Historical Park. Seismic waves may also undermine slope stability and increase local spalling along the cliffs.

Research and monitoring questions and suggestions include:

- Promote the development of an active seismic network for the area.
- Evaluate risk for tsunami and shoreline damage due to earthquake activity and continental slope landslides.
- Evaluate cultural features at risk for damage during infrequent seismic events.

7. Land use evolution

Early settlement uses of the landscape included tobacco plantations and other agriculture. After a few years of overuse, most plantations suffered widespread depletion of soil nutrients. Glauconite and shell material were extracted from the Yorktown Formation for use as soil additives to boost tobacco production.

Iron rich cements in the local deposits sparked local interest in iron ore extraction through the Civil War. Iron minerals such as limonite and goethite are part of the ledge forming units at the top of the Yorktown and overlying units. These minerals form cements as iron and magnesium precipitate during carbonate dissolution. Colonials and slaves removed large chunks of these iron rich rocks to transport to furnaces.

Historic manipulation of the hydrogeologic system of the area has also left remnants on the colonial landscape. Several of the areas waterways were dammed for hydroelectric power, such as the Jones Mill pond. The Wormley Pond area was lost to damage during Hurricane Floyd in 1999. The earthen dams associated with the Augustus Moore mill were present during the signing of the treaty at the end of the Revolutionary War. Now due to forest management and uprooted trees, the earthen dams are at risk of being washed away.

Land use evolution continues today as increasing developments threaten the colonial viewshed of the parks and parkway. Human impacts include pipelines, power lines, roads, buildings, trails, visitor use areas, invasive species, acid rain, and air and water pollution. Effects from these developments also include groundwater level changes, an increase in impermeable roadways, the interruption and contamination of spring flows. The Greenspring Planation Development may threaten the colonial Greenspring: an early water source.

Research and monitoring questions and suggestions include:

- Will the Greenspring continue to flow?
- Identify areas to target for remediation of viewshed damage from encroaching development.
- Promote studies correlating land use changes with movement of Native Americans and early settlers.
- Keep rigorous track of land use and development and create community profiles in surrounding areas. Possibly employ a GIS to monitor land use changes.
- Cooperate with local developers to minimize impact near park areas.
- Is runoff in the park increasing due to surrounding development? If so, are there any remedial efforts resource management can undertake to reduce this impact?
- Consult conservation groups regarding cooperative efforts to increase the areas of relevant parklands and protect more of the region from development.
- Promote environmentally sound methods of developing land parcels including partial clearing of trees and proper construction of stable slopes.
- Create programs interpreting geologic features and processes and their effects on the settlement history of the area.

8. Water issues including surficial water, storm water management, and groundwater hydrogeologic characterization

Streams cut the through the Coastal Plain deposits creating the rolling hills, ravines, and bluffs that are characteristic of the landscape at Colonial National Historical Park. These streams include Yorktown, Mill, Powhatan, Kingsmill, Passmore, and Ballard Creeks, and the Back River. In the Jamestown area, these streams are removing cultural resources and expanding wetlands continue to inundate the landscape.

Streams and stormwater are piped under the Colonial Parkway. Culverts in place to facilitate water movement in many cases are ~75 years old and are often inadequate to handle peak flows. Erosion and sedimentation from stormwater remains a problem along the length of the parkway. This erosion is threatening cultural features including unexcavated archaeological sites. Long- term changes and repairs are proposed in conjunction with an assessment regarding federal highways (I- 64 corridor).

Research and monitoring questions and suggestions include:
- Promote countywide subbasin and watershed studies.
- Are the sewer lines connecting Gloucester with the Hampton Roads system affecting local water quality?
- What remediation is necessary for old culverts along the Parkway?
- Promote revegetation in areas of significant gullying and erosion.

9. Slope processes

Slope processes and erosion are continuously changing the landscape at Colonial National Historical Park. Shoreline erosion is of utmost concern for resource management because many historic features and cultural resources have been lost and/or remain at risk along the park's shorelines. Storm events cause extreme erosion along the park's slopes. Falling trees releasing pulses of material to streams as well as removing stabilizing roots facilitate much of this erosion. Lake of stabilizing vegetation leads to increased erodability of most slopes in the area.

Research and monitoring questions and suggestions include:
- What if any slope stability impacts exist?
- Can cliff erosion be slowed or stopped?
- Identify problem reaches for immediate remediation.
- Develop a slope monitoring plan for the park.

10. Disturbed land sites

Disturbed lands include a Superfund site along the parkway. The naval weapons station acts as a jetty of sorts, changing fluvial sediment transport in the York River. Associated with the naval weapons station in the York River was a pre-WWII fuel farm. This feature currently leaks pollution into the local ecosystem. A mercury leak posed a problem along Ballard Creek. Restoration efforts for these sites includes stabilization of sites with warm season sea grasses and improved storm water management.

The Virginia Division of Mineral Resources knows of an abandoned borrow pit on or near parklands. Jurisdiction of this feature is unknown at this time.

A problem area associated with the construction of I- 64 is threatening a riparian ecosystem through park property near the Colonial Parkway. This feature is a deep 3- 4 m (10 to 12 ft) gully and contributes excess sediment to the York River and Chesapeake Bay. Erosion is facilitated by heavy rains and a lack of stabilizing vegetation in the borrow area. The highway blocks natural water flow and its impermeable surface greatly adds to storm runoff. Stormwater culverts along the highway concentrate erosive flow (NPS, 2005).

Research and monitoring questions and suggestions include:

- Define goals for the desired future conditions of the gully associated with I-64. This may or may not include stabilizing the gully and developing a watershed restoration plan with adjacent landowners and managers for upstream reaches of the park's waterways.
- Promote revegetation of affected areas adjacent to parklands to curtail excessive erosion.
- Cooperate with local, state, and federal agencies to remediate disturbed lands within and surrounding the park.

11. Unique geologic features including a type section for the Moorehouse Member of the Yorktown Formation at Moorehouse Cliff

The upper layers of the Yorktown Formation include a shelly hash unit known as the Moorehouse Member. This unit contains abundant fossils including the Virginia State *Fossil (Chesapecten jeffersonius)*. Other fossils include 3 Ma shark teeth, whale and walrus bones, and scallop shells. Fossils weather out of the Yorktown and are found along the shorelines of the local waterways. The type section for this member is along the cliffs below Moorehouse at Yorktown. A type section is gernerally the first place a particular geologic unit is described, though this location may change to describe the best field example of the unit. In other words, the geologic definition of a particular unit is recorded at its type section.

Research and monitoring questions and suggestions include:

- Perform a geologic survey of the Parkway.
- Identify all reaches of exposed shelly layers within the Yorktown Formation and slumps and washes below it to target for fossil protection.

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References

Bailey, C.M., 1999, Generalized Geologic Terrane Map of the Virginia Piedmont and Blue Ridge. http://www.wm.edu/geology/virginia/terranes.html

Duffy, D.F., Whittecar, G.R., 1991, Geomorphic development of segmented alluvial fans in the Shenandoah Valley, Stuarts Draft, Virginia. Abstracts with Programs - Geological Society of America, vol.23, no.1, p.24.

Harris, A.G., Tuttle, E., Tuttle, S.D., 1997, Geology of National Parks. Kendall/Hunt Publishing Company, 759 p.

Johnson, G., Hobbs, C., Mrozowski, S., Currie, D., Kelso, G., Blanton, D., Kealhofer, L., Horning, A., 2001, Geological Development and Environmental Reconstruction of Jamestown Island, Jamestown Archaelogical Assessment 1992- 1996. Prepared for the National Park Service by the Colonial Williamsburg Foundation and the College of William and Mary, 192 p.

Kenworth, J., Santucci, V.L., 2003, Paleontological Resource Inventory and Monitoring – Northeast Coastal and Barrier Network. U.S. Department of the Interior, National Park Service, TIC # D- 340.

Means, J., 1995, Maryland's Catoctin Mountain parks; an interpretive guide to Catoctin Mountain Park and Cunningham Falls State Park. McDonald & Woodward Publishing Company : Blacksburg, VA, United States, 168 p.

Mixon, R.B., Pavlides, L., Powars, D.S., Froelich, A.J., Weems, R.E., Schindler, J.S., Newell, W.L., Edwards, L.E., Ward, L.W., 2000, Geologic Map of the Fredericksburg 30’x60’ Quadrangle, Virginia and Maryland. U.S. Geological Survey, Geologic Investigations Series Map I- 2607, 1:100,000 scale.

National Park Service, 2005, Memorandum, September 29, 2004, Site Visit – Evaluation of Disturbed Land Site at Colonial National Historical Park (COLO). Prepared by Pranger, H. through Woods, J., and Steensen, D., Geoscience and Restoration Branch (GRB), 12 p.

Onasch, C.M., 1986, Structural and metamorphic evolution of a portion of the Blue Ridge in Maryland. Southeastern Geology, Vol. 26, Issue 4, pp. 229- 238.

Southworth, S., Brezinski, D.K., Orndorff, R.C., Chirico, P.G., Lagueux, K.M, 2001, Geology of the Chesapeake and Ohio Canal National Historical Park and Potomac River Corridor, District of Columbia, Maryland, West Virginia, and

Virginia; A, Geologic map and GIS files (disc 1); B, Geologic report and figures (disc 2). U. S. Geological Survey, Open- File Report: OF 01- 0188.

Whittecar, G. R., Duffy, D.F., 2000, Geomorphology and stratigraphy of late Cenozoic alluvial fans, Augusta County, Virginia, U.S.A. In: Regolith in the Central and Southern Appalachians, Clark, G.M., Mills, H.H., Kite, J.S., eds., Southeastern Geology, vol.39, no.3- 4, p.259- 279.

Map of Colonial National Historical Park